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Mechanical Testing of Carbon Based Woven Thermal Protection Materials

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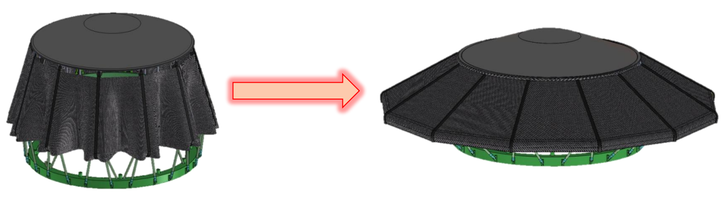
Objective

Assessment of the structural integrity of 3-D woven carbon cloths that have undergone heating similar to Venus atmospheric entry conditions.

Background

- Planetary Science Decadal Survey expresses interest in Venus
- NASA proposes Venus Intrepid Tessera Lander (VITAL) mission
- Implement game changing technology of adaptable, deployable entry placement technologies (ADEPT)
  - Δ Requires novel thermal protection system (TPS)
  - Δ Low ballistic coefficient → more benign entry conditions



Stowed — Prior to Landing

BLAM Testing

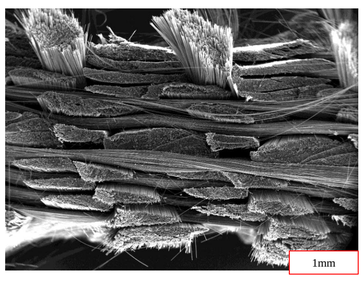
- Bi-axial load aerothermal mechanical (BLAM) testing
- Evaluate woven TPS under entry conditions

Model	Heat Flux on Fabric (W/cm²)	Warp Running Load (N/cm)	Weft Running Load (N/cm)	Exposure Time (sec)
B1	136	1310	660	35
B2	97	660	330	135
B3	97	1310	660	139

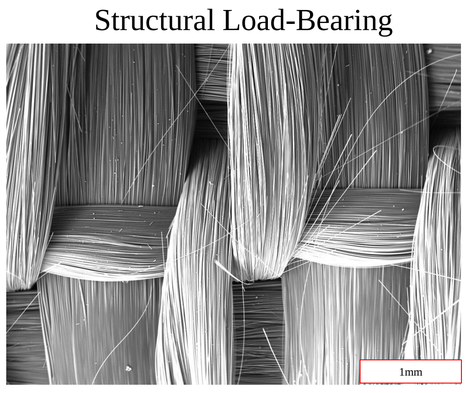
Thermal Protection System

- Novel 3-D woven, flexible carbon cloths
  - Δ Tailorable weave patterns and properties
  - Δ Interwoven weave architectures provide structural load and heat shield TPS
  - Δ One such architecture imaged on right
  - Δ Structural and thermal layers below

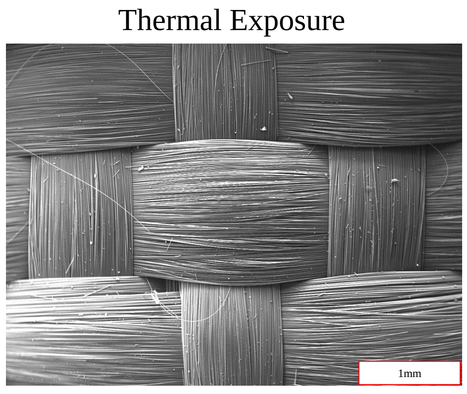
Profile View



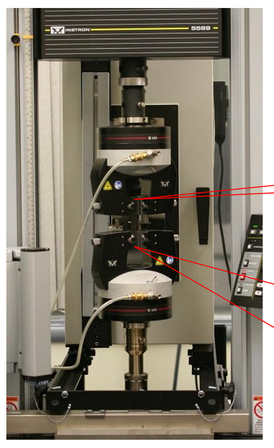
Bottom Layers
Structural Load-Bearing



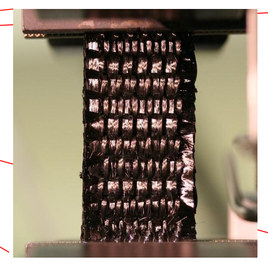
Top Layers
Thermal Exposure



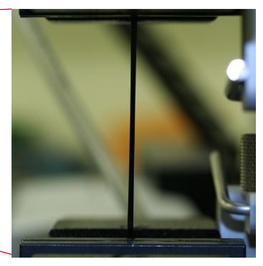
Mechanical Testing



- Instron 5569, $\dot{\varepsilon}$ = 1mm/min
- Fabric and yarns, pre and post aerothermal exposure



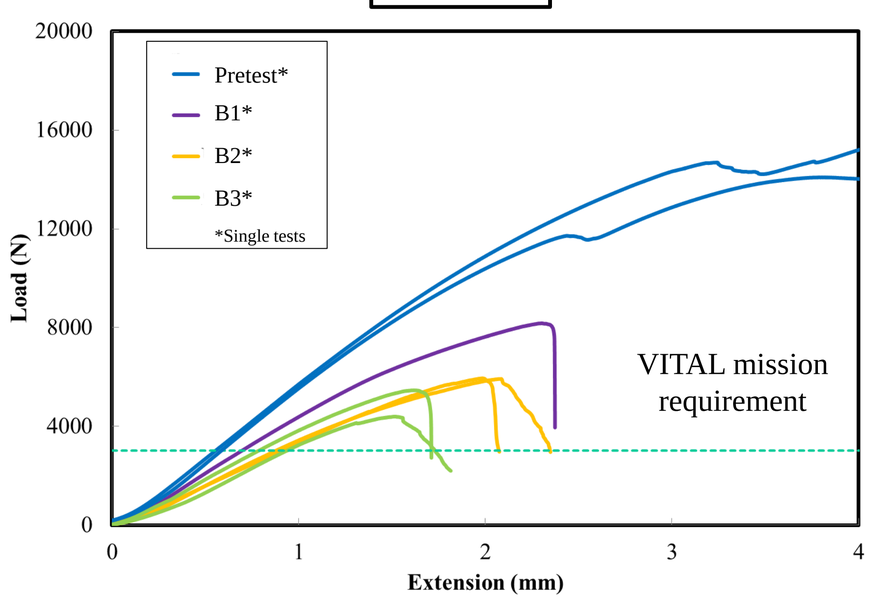
Fabric

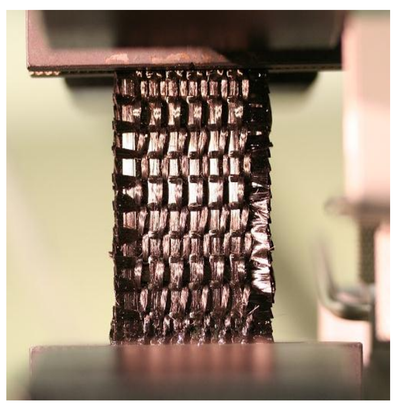


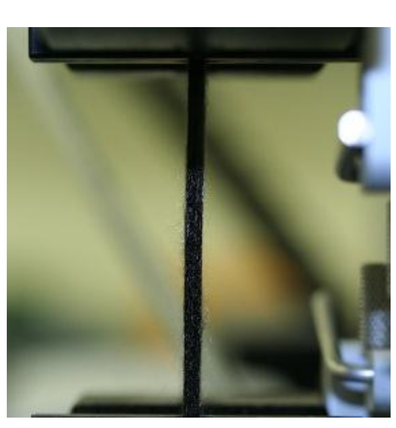
Yarn

Results

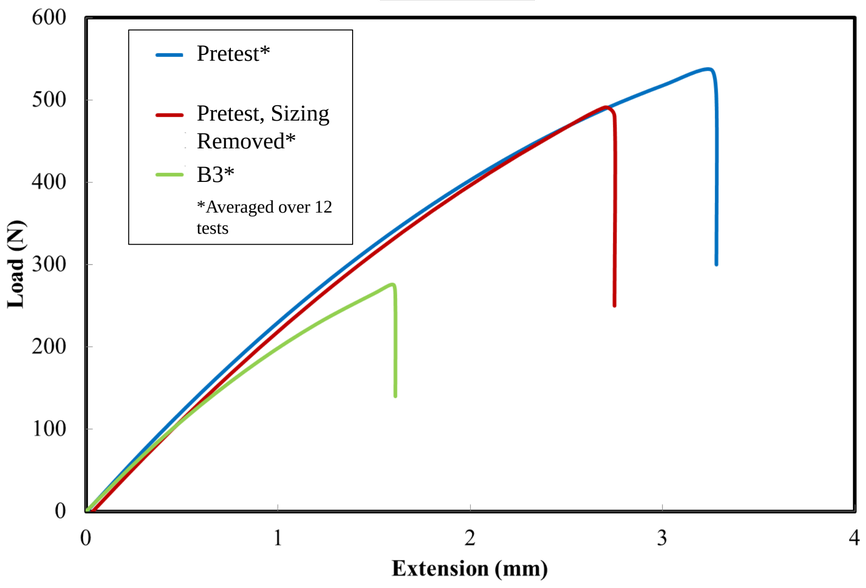
Fabric Test







Yarn Test



Observations

- Post-exposure strength exceeds flight requirement
- BLAM testing appears to cause fabric embrittlement
- Reduction in mechanical properties correlated with exposure duration

- Imaged above: Woven fabric at 4 minutes, weave elongation
- Lower image: Failed yarn, bundle loosening

Conclusion

- Data indicates that aerothermal heating reduces mechanical strength
- Arcjet exposure appears to cause embrittlement
- Mechanical testing provides design guidelines for future woven TPS

Forward Work

- Investigate the causes of embrittlement and reduction in load bearing capacity due to aerothermal heating
- Isolate effects of oxidation and thermal exposure on mechanical performance
- Additional fabric testing to statistically verify mechanical property reductions

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